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EXPERIMENTAL STUDIES OF A COMBINED AGGREGATE FOR APPLICATION OF MINERAL FERTILISERS AND SOWING

Volodymyr BULGAKOV[1], Semjons IVANOVS[2], Valerii ADAMCHUK[3], Ievgenii PETRYCHENKO[3], Zinovii RUZHYLO[1], Janusz NOWAK[4]
[1]National University of Life and Environmental Sciences, UKRAINE
[2]Latvia University of Agriculture, LATVIA
[3]National Scientific Centre "Institute for Agricultural Engineering and Electrification", UKRAINE
[4]University of Life Sciences in Lublin, POLAND
E-mail of corresponding author: semjons@apollo.lv

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ABSTRACT
The article presents the results of field experimental studies of sowing grain crops and application of mineral fertilisers by means of a combined two-machine fertiliser application and sowing aggregate on the basis of two grain seeders. A regression equation is obtained, and influence of the velocity of movement, the depth of sowing seeds and application fertilisers into the soil upon the uniformity of seed and fertiliser distribution along the row are determined. On the basis of the obtained experimental data rational parameters of sowing are justified at which the necessary quality of the execution of the technological process will be achieved.

INTRODUCTION

As one of the basic ways how to increase the efficiency of crop production may be regarded elaboration of the ways for raising the efficiency of aggregates and decreasing the costs for the execution of technological operations. An analysis shows that the most perspective way for essential decreasing the costs when growing grain crops is the use of combined sowing aggregates which simultaneously perform several technological operations of sowing (Kabakov, 1984; Behov and Djachenko, 2000; Vilde et al., 2006; Chorna, 2012). There are several variants of combined machines for application of fertilisers and sowing. The present article considers a possibility to use a combined sowing aggregate for the application of mineral fertilisers and sowing on the basis of two grain seeders. The seeders are trailed by tractor of the traction class 14 kN, which is the most widespread among the agricultural producers in many countries of Eastern Europe. The main advantage of this fertilising and sowing aggregate is to introduce the basic dose of mineral fertilisers into deeper layers of the soil, directly into the area of the future root system of the crop. Justification of the scheme, design parameters and operating modes of the sowing aggregate created by using tractors of the traction class 1.4 on the basis of two trailed grain seeders is outlined in works (Masalabov, 2016; Petuhov, 2016). However, considering the difference between the proposed aggregate and those treated in the works mentioned, a necessity arises to conduct experimental studies about the influence of the sowing parameters upon the execution quality of the process and justification of their rational values. The aim of this study is experimental determination of the influence of the working velocity of the combined sowing aggregate, the depth of sowing seeds and application fertilisers into the soil upon the uniformity of seed distribution, as well as determination of rational parameters.

MATERIALS AND METHODS

The experimental equipment (Fig. 1) consists of two seeders connected together by a special hitch which allows ensuring the necessary manoeuvrability of the aggregate during its operation. During the execution of the process the first seeder of the sowing aggregate ensures introduction of the necessary basic dose of mineral fertilisers into the soil to the depth of 7 to 9 cm with a row spacing of 25 cm but the second seeder – sowing of the grain crops to the depth 2 to 6 cm with a row spacing of 12.5 cm with simultaneous introduction of the starting dose of mineral fertilisers. As a means of aggregation a tractor of the traction class 14 kN is used.

Fig. 1. General view of the experimental equipment

Barley seeds were used for the laboratory and field studies of the sowing process, but, for better estimation of the distribution of mineral fertilisers in the furrow, it was replaced by soya bean seeds. Besides, as quality indicators of the operation there were accepted the uniformity of seed and fertiliser distribution along the row, the coefficient of the seed and fertiliser sowing depth variation, and the deviation coefficients of the seeds and fertilisers from the axis of the row – factors which affect qualitative indicators of work – the sowing depth of seeds and fertilisers, as well as the operating velocity of the forward movement of the aggregate. The sowing depth of the seeds was accepted as 2, 4, 6 cm, the sowing depth of the fertilisers – 7, 8, 9 cm, and the working velocity of the aggregate – 1.0, 2.0, 3.0 $m \cdot s^{-1}$. The object of the experimental studies is the operating process of sowing by means of the proposed combined two-machine sowing aggregate. The conditions for the execution of the studies, fixed according to known methodologies (Dospehov, 1985; Barwicki et al., 2012). The results of the experimental studies were processed according to a well-known methodology of statistical processing of research data (Maslov, 2007) with subsequent presentation in the form of functional and graphical dependencies, as well as with the application of applied programs for the PC.

RESULTS AND DISCUSSION

As a result of the conducted experimental studies according to the accepted methodology the following dependencies were obtained. The uniformity of barley seed distribution along the row will be described as a regression equation in the form of a polynomial of the second degree, like:

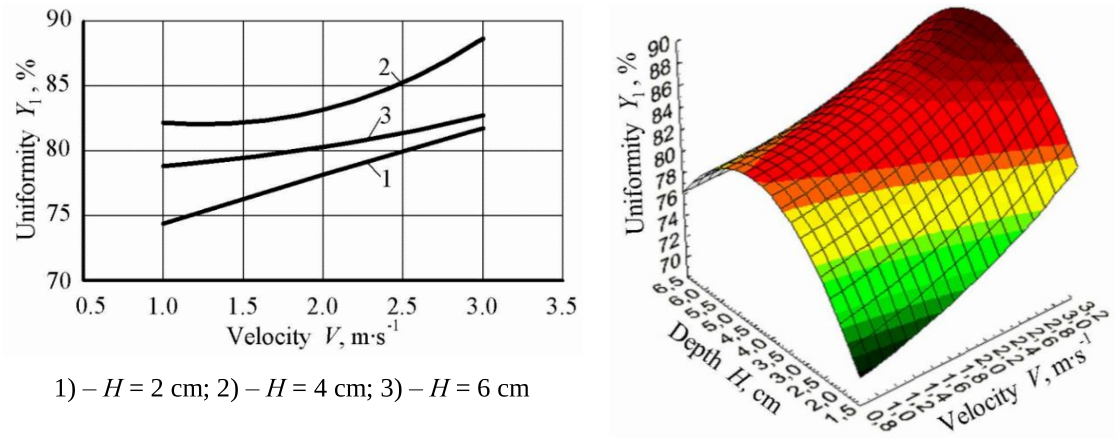
$$Y_1 = 54.33+1.21 \cdot V+12.1783 \cdot H+0.865 \cdot V^2-0.4163 \cdot V \cdot H-1.3388 \cdot H^2, \qquad (1)$$

where: Y_1 – uniformity of barley seed distribution along the row (distance between seeds), %; V –working velocity of the sowing aggregate, $m \cdot s^{-1}$; H – sowing depth, cm.

On the basis of the analysis of the obtained equation (1), as well as its graphic interpretation (Fig. 2) one can draw a conclusion about the increase in the sowing uniformity of the seeds when the velocity of the forward movement of the aggregate. But when the sowing depth of the seeds is increased from 2 to 4 cm, this quality indicator of the operation will increase; when the depth is increased further – the uniformity will decrease. For the indicator “uniformity of fertiliser (soya bean seeds) distribution along the row” the following response surface (Fig. 2) and a regression equation were obtained:

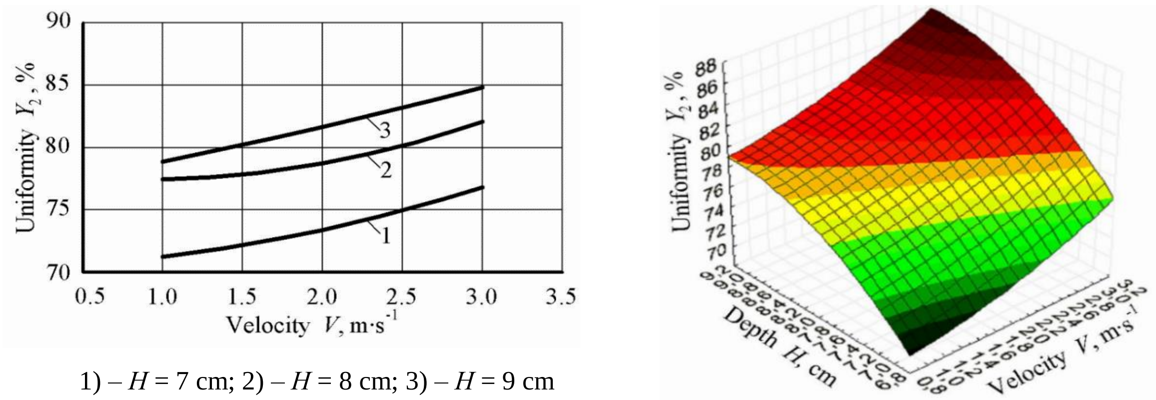
$$Y_2 = -60.6811 - 0.4867 \cdot V + 30.41 \cdot H + 0.6167 \cdot V^2 + 0.09 \cdot V \cdot H - 1.6633 \cdot H^2, \qquad (2)$$

where: Y_2 – uniformity of fertiliser (soybean seeding) distribution along the row (distance between seeds), %.



a) b)

Fig. 2. Dependencies of the uniformity of barley seed distribution along the row upon velocity V of the sowing aggregate and sowing depth H of the seeds (a), and the response surface (b).



a) b)

Fig. 3. Dependencies of the uniformity of fertiliser (soybean seeding) distribution along the row upon velocity V and the introduction depth H of fertilisers into the soil (a), and the response surface (b).

Increasing the working velocity of the sowing aggregate and the introduction depth of fertilisers into the soil, the uniformity of their distribution at the bottom of the furrow will increase. The analysis of the obtained research results (Fig. 3) also indicated a decrease in the variation coefficient of the sowing depth of the barley seeds when the working velocity of the aggregate and the sowing depth of the seeds increase. This is also determined by the obtained functional dependency:

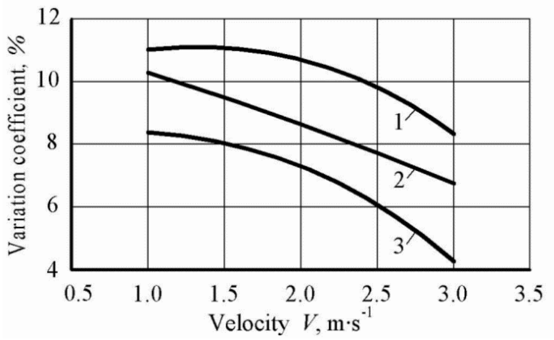
$$Y_3 = 10.79 + 1.7883 \cdot V - 0.05 \cdot H - 0.705 \cdot V^2 - 0.18 \cdot V \cdot H - 0.055 \cdot H^2, \qquad (3)$$

where: Y_3 – variation coefficient of the sowing depth of the barley seeds, %.

The graphic dependency of the variation coefficient of the sowing depth of fertilisers (soya bean seeds) upon the working velocity of the sowing aggregate and the depth of the fertiliser placement into the soil is presented in Fig. 4, but the equation which will describe this dependency will have the following appearance:

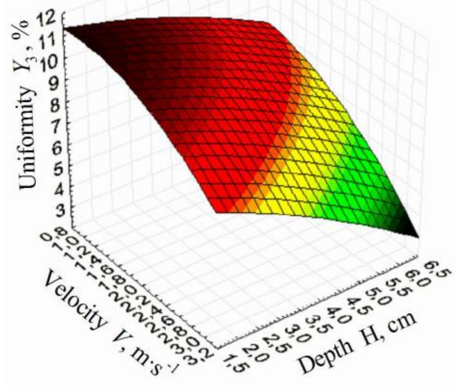
$$Y_4 = 25.7444–14.89·V+2.6967·H+0.4533·V^2+1.3825·V·H–0.4417·H^2, \quad (4)$$

where: Y_4 – variation coefficient of the sowing depth of the fertilisers (soybean seeding), %.



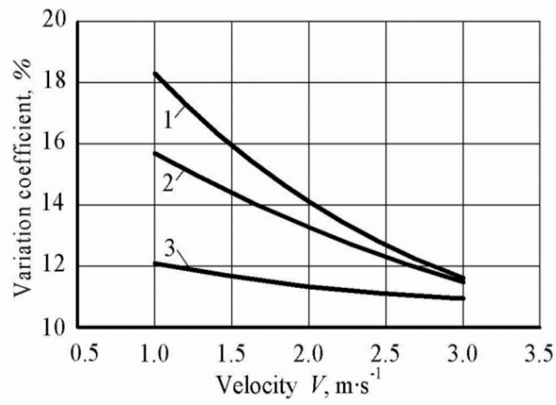
1) – H = 2 cm; 2) – H = 4 cm; 3) – H = 6 cm

a)



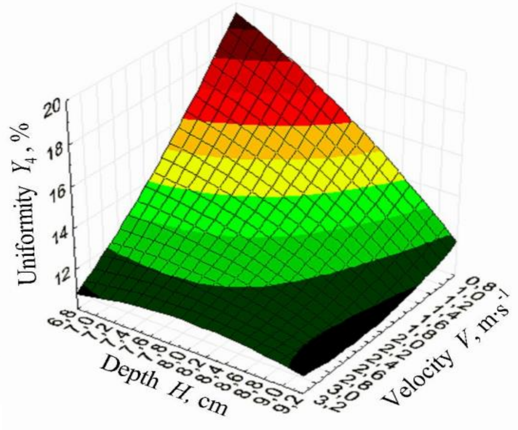
b)

Fig. 4. Dependencies of the variation coefficient of the sowing depth of the barley seeds upon velocity V and sowing depth H of the seeds (a), and the response surface (b).



1) – H = 7 cm; 2) – H = 8 cm; 3) – H = 9 cm

a)



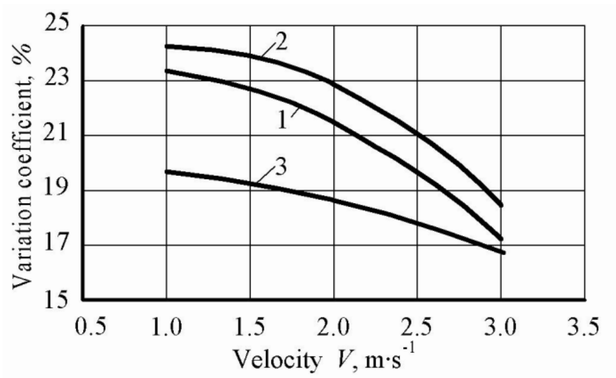
b)

Fig. 5. Dependencies of the variation coefficient of the fertiliser (soybean seeding) introduction depth upon velocity V and the depth H of placement of fertilisers into the soil (a), and the response surface (b).

The obtained results of the studies witness that decreased deviation of the introduction depth of fertilisers into the soil from the preset value can be achieved by increasing the working velocity of the aggregate and the placement depth of fertilisers. The obtained results of the experimental studies (Fig. 6) indicate also a decrease in the variation coefficient of the deviation from the axis of the row of the barley seeds when the velocity of the sowing aggregate is increased. But, increasing the sowing depth from 2 cm to 4 cm, the variation coefficient rises, but after further increase in the depth – the variation coefficient diminishes. The regression equation has the following form:

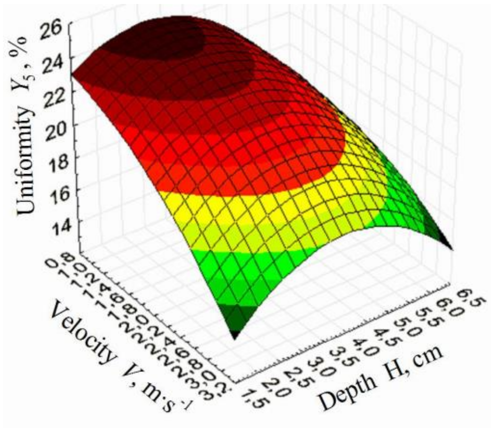
$$Y_5 = 19.5111+0.07·V+3.3433·H–1.0417·V^2+0.3987·V·H–0.5904·H^2, \quad (5)$$

where: Y_5 – variation coefficient of the deviation from the axis of the row of the barley seeds, %.



1) – *H* = 2 cm; 2) – *H* = 4 cm; 3) – *H* = 6 cm

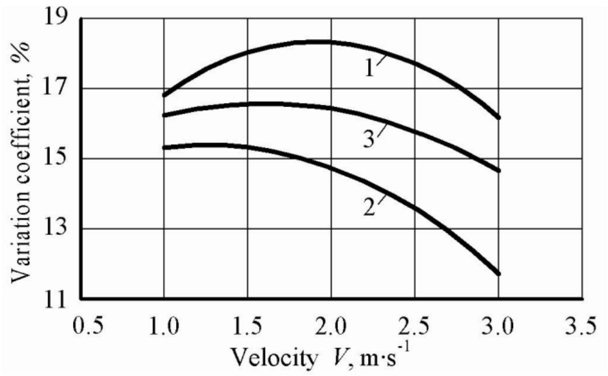
a)



b)

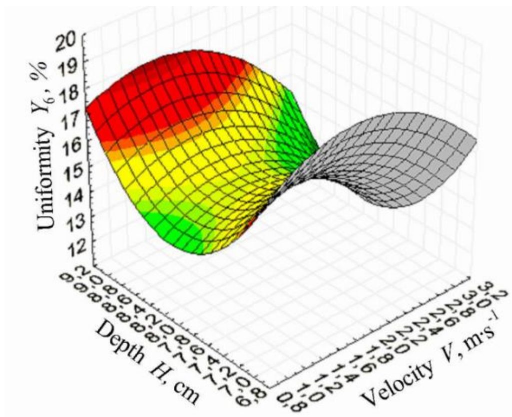
Fig. 6. Dependencies of the variation coefficient of deviation from the axis of the row of the barley seeds upon velocity *V* and the sowing depth *H* of seeds (a), and the response surface (b).

On the basis of the presented results of the experimental research of the influence of the sowing parameters upon the variation coefficient of deviation from the axis of the fertiliser row (Fig. 7) one can draw a conclusion about a decrease in its value when the working velocity of the aggregate is increased. However, when the depth of the fertiliser introduction is increased, the variation coefficient will diminish, but, when the depth is increased, it, on the contrary, will increase.



1) – *H* = 7 cm; 2) – *H* = 8 cm; 3) – *H* = 9 cm

a)



b)

Fig. 7. Dependences of the variation coefficient of deviation from the axis of the fertiliser (soybean seeding) row upon velocity V (a), and the response surface (b).

This will be confirmed also by the analysis of the regression equation:

$$Y_6 = 175.0711+6.2817\cdot V-40.7283\cdot H-1.3517\cdot V^2-0.2325\cdot V\cdot H+2.5333\cdot H^2, \quad (6)$$

where: Y_6 – variation coefficient of the deviation from the axis of the row of the fertiliser (soybean seeding), %.

On the basis of the factor analysis of the obtained regression equations (1-6) there are determined rational parameters of sowing grain crops using a combined two-machine sowing aggregate: the working velocity of the aggregate – 2.5...3.0 m·s^{-1}, the sowing depth of the seeds – 4...5 cm, the depth of fertiliser introduction into the soil – 8...9 cm. Results of the research were given patent for construction (Adamchuk et al., 2015). The results of the conducted experimental studies made it possible to determine also the technical and operational performance indicators of the particular combined fertilising and sowing aggregate (Table 1).

Table 1. Technical and operational performance indicators of the combined fertilising and sowing aggregate

Name of the parameter	**Value**
Turning radius, m	6.5…8.9
Turning time, s	18.4…24.7
Average velocity on the turning strip, m s^{-1}	1.78
Average deviation of the path of the second seeder in relation to the path of the first seeder, see: -at the turn -during the working travel	 23.7 3.6
Specific fuel consumption, l ha^{-1}	3.77

As evident from the data in Table 1, the turning radius of the particular combined fertilising and sowing machine and tractor aggregate does not exceed 9 m, which ensures its «looping» turns but deviations of the path of the second seeder in relation to the first one also have an insignificant value, which is 23.7 cm and is also quite acceptable.

CONCLUSIONS

1. For a combined aggregate for the introduction of mineral fertilisers and sowing on the basis of two seeders a regression equation has been obtained and impact of the working velocity, the sowing depth of seeds and the introduction depth of fertilisers into the soil has been determined upon the distribution uniformity of seeds and fertilisers along the row.

2. Rational values of the sowing parameters of the barley seeds by a combined sowing aggregate are: the working velocity– 2.5...3.0 m s^{-1}; the sowing depth of seeds – 4...5 cm; the introduction depth of fertilisers into the soil – 8...9 cm

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